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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

BULLETIN No. 47

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

APPLICATION OF THE PRINCIPLES OF JELLY MAKING TO HAWAIIAN FRUITS

BY

J. C. RIPPERTON, Chemist

Issued June 21, 1923

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[Under the supervision of the States Relations Service, United States Department of Agriculture.]

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H. L. CHUNG, *Specialist in Tropical Agronomy.*
W. T. POPE, *Horticulturist.*
J. C. RIPPERTON, *Chemist.*
R. A. GOFF, *In Charge of Glenwood Substation and Extension Agent for Island of Hawaii.*
NELLIE A. RUSSELL, *Collaborator in Home Economics.*

APPLICATION OF THE PRINCIPLES OF JELLY MAKING TO HAWAIIAN FRUITS.

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INTRODUCTION.

Although tropical fruit products have been given wide publicity within recent years and there is an ever-increasing demand for them on the world markets, jelly making from tropical fruits remains as yet a comparatively undeveloped industry. Probably the only two tropical fruit jellies of any commercial importance at the present time are those made from guava (*Psidium guayava*) and poha (*Physalis peruviana*). Guava jelly, owing to the comparatively small cost of production and the growing of the wild fruit in abundance, is the standard jelly as well as the basic product of the fruit jelly industry in Hawaii. Poha jelly production is as yet small, owing to the limited supply and high cost of the fruit. Since the exportation in the fresh state of many Hawaiian fruits is prohibited by quarantine regulations, the fruit jelly-making industry in Hawaii should serve as a stimulus for producing and exporting Hawaiian fruit products in greater abundance than is now the case.

Extensive studies have been made of, and formulæ developed for, the making of jellies from every important fruit of the Temperate Zone, but little or no study has been devoted to the making of jelly from fruits from the Tropics. The writer, therefore, made an exhaustive study of the Hawaiian guava for jelly making for the purpose of developing a systematic procedure by means of which jelly may successfully be made from any kind of jelly fruit.[1] This bulletin gives the results of the investigation.

METHODS.

A review of the different studies on jelly making showed that there are no generally accepted methods for conducting a systematic study of the jelly-making qualities of a fruit, and that the tendency is to develop formulæ for different fruits rather than general principles which will apply to all jelly fruits. The methods followed by the writer require little time and simple apparatus, and while the results obtained from their use can not be considered in the light of accurate quantitative results, they are, it is thought, sufficiently accurate for a practical study of jelly making.

[1] A fruit containing the essential constituents for jellying, i. e., pectin and acid.

DETERMINATION OF PECTIN IN FRUIT JUICES.

Careful search through literature failed to give any quick, practical method for determining the pectin content of fruit juices. As a rule the pectin content is not determined, and the quantity present is indicated by specific gravity or by means of the Brix hydrometer.

The Brix reading indicates at once the proportion of sugar that should be added to the juice in accordance with tables that have been worked out for apple juice, but since such tables are of no value in connection with other fruits a separate table must be constructed for each specific fruit.

Home economics text and cook books commonly advocate the method of adding fruit juice to alcohol in a tumbler to determine the pectin content of a juice. The appearance of the precipitated pectin when poured out is taken as an indication of the content, the juice being said to contain a high percentage of pectin when the precipitate pours out in a single lump, only a medium quantity when there are several small lumps, and not enough pectin for jelly making when there are no lumps. Many substances, such as magnesium sulphate, can be used in place of alcohol to precipitate the pectin. This method, while valuable for the housewife, was not deemed sufficiently accurate to be of use in connection with the present investigation.

Quantitative methods entailing precipitation, filtration, weighing, and ignition require too much time for completion to be of practical use in jelly making.

By means of a cylinder, graduated to 25 cubic centimeters and fitted with a plunger,[2] a pipette, to deliver the juice to the alcohol drop by drop, and a piece of silk bolting cloth about 4 inches square, the writer developed a method for determining the pectin content of fruit juices. (Pl. I, Fig. 1.) After 20 cubic centimeters of 95 per cent ethyl alcohol were measured into the cylinder, 10 cubic centimeters of the juice to be tested were added drop by drop to the alcohol. The contents of the cylinder was then filtered through the silk bolting cloth, which was rolled back and forth in the hand until the pectin precipitate gathered into a compact mass and the alcohol ceased to run out.[3] As soon as the pectin mass had been rolled into cylindrical shape it was slipped into the cylinder and shaken to the bottom. The plunger was then placed on top of the mass and the volume in cubic centimeters, or "pectin number," was noted. The operation required only three to five minutes with most of the juices tested, and duplicate results were had within a quarter of a cubic centimeter.

The amount of alcohol which the pectin mass will retain depends of course on the pressure exerted. The purpose of rolling on the silk cloth is to remove the excess alcohol with no pressure at all other than that exerted by its own weight. The purpose of the plunger is not to exert pressure, but to make possible an accurate reading of the pectin number.

The relationship existing between the "pectin number" and the percentage of pectin was determined by ascertaining the alcohol precipitate, that is, the impure pectin, for which purpose the method

[2] A Nessler tube having the proper diameter can be used as the plunger.

[3] In this operation time can be saved by placing the cloth upon a folded towel to absorb the alcohol, but the results obtained are not nearly so accurate as when no towel is used.

followed by the Association of Official Agricultural Chemists was used.[4]

Table 1 gives the "pectin number" and percentage, as well as the Brix hydrometer reading of several guava juices and of one juice each of the poha, grape, and roselle.

TABLE 1.—*Comparison of "pectin number" and pectin per cent in fruit juices.*

Fruit juice.	Pectin.		$\frac{b}{a}$	Brix reading.	Character of precipitate.
	a	b			
	Number.	*Per cent.*		*Degrees.*	
Guava	3½	0.446	0.137	3.6	Spongy with medium long fibers.
Do	4½	.578	.136	5.2	Do.
Do.[1]	5½	.794	.151	7.0	Do.
Do	6½	.963	.148	7.8	Do.
Do	7½	1.141	.157	11.8	Do.
Do	9¼	1.661	.180	9.6	Do.
Poha	2½	.431	.172	15.4	Dense with long, tough fibers.
Grape	4	.888	.222	12.6	Gelatinous with very short fibers.
Roselle	5¼	.977	.186	3.8	Spongy with short fibers.

[1] Average.

Table 1 shows that the factor $\frac{b}{a}$ is fairly constant for guava juice. Any increase in this factor for juices having a higher pectin content is, of course, due to the increased pressure exerted by the greater bulk of precipitate and the resultant smaller proportion of alcohol remaining in the mass. Guava juices, however, seldom contain a pectin number greater than 7½ or less than 3, and the factors within this limit vary only little.

The factors for the juices of different fruits vary considerably. This variation is directly traceable to the character of the precipitate because the swelling power of the precipitate, or its capacity to absorb alcohol, varies with the character of the pectin.

The Brix reading of a juice, as an indication of the pectin content, is unreliable, unless only one fruit is used in the experiment. The percentage of pectin in a juice may be computed by multiplying its pectin number by the factor $\frac{b}{a}$. This method of computation was used throughout the investigation.[5]

PROPORTION OF SUGAR TO JUICE.

The following method was used for systematically determining the best proportion of sugar to add to the fruit juice.

A series of jellies was made with varying quantities of sugar to 1 cupful[6] of juice, a start being made with three-quarters of a cupful of sugar to 1 cupful of juice. The quantity of sugar was increased a quarter of a cup at a time until a sirup or gummy mass instead of a

[4] Methods of Analysis of the Association of Official Agricultural Chemists. Revised to Nov. 1, 1919 Washington, D. C., 1920, p. 156.

[5] For use of the "pectin number" method in investigational work, each worker should determine the factor $\frac{b}{a}$ for himself so as to eliminate eventually the personal factor. For practical work, however, variations due to this cause are negligible.

[6] Wherever the term "cupful" is used in connection with measurements of juice and sugar, 245 cubic centimeters of juice and 200 grams of granulated sugar are taken as the equivalent. The actual volume of a half-pint cup is 236.6 cubic centimeters. However, the value assumed is believed to be nearer the actual measurements, made by the average jelly maker, than the true value.

jelly resulted. The resultant "jelly series" was then studied to determine the relative merits of each of the different proportions of sugar to juice. Each member of the series was brought up to as standard a consistency as possible.

CHEMICAL ANALYSIS OF JUICES AND JELLIES.

The methods of analysis recommended by the Association of Official Agricultural Chemists[7] were employed in making analyses of the juices and jellies. Sucrose was determined by polarization before and after inversion with hydrochloric acid, reducing sugar, by the volumetric Fehling-solution method of Munson and Walker, and crude pectin, by the alcohol precipitate method. The acidity was then determined by titrating with fifth-normal sodium hydroxid, with phenolphthalein as indicator. Phenolphthalein sufficed for work of a practical nature, even with the highly colored juices studied, since the natural color of the juice faded somewhat, usually changing to pale green, before the end point with the indicator was reached and the color change of the latter was therefore readily discernible.

THE GUAVA FOR JELLY MAKING.

The common guava, which is used for jelly making, is a conspicuous part of the native vegetation of Hawaii. It grows over wide ranges of altitude and rainfall and on both the windward and the leeward sides of all the islands. The ripe fruit can be obtained the year round, but the main crop is produced from June to October.

Although many of the large guava-producing areas are leased by commercial jelly companies, large numbers of guava shrubs are to be found growing along highways and on public lands where the fruit can be had for the picking. It is seldom found for sale on any of the markets, and the average housewife picks her guavas from whatever source she can obtain them. Probably the only well-established rule governing the selection of guavas in Hawaii is that fruit from the windward side of the island is inferior for jelly making to that on the leeward side.

COMPOSITION OF GUAVA JUICE.

To determine the composition of the juice of an average guava for jelly-making purposes, 5 pounds of medium ripe guavas was cooked in 2.5 pounds of water for one hour and then allowed to drain overnight. When it was analyzed, the juice was found to have the following composition:

TABLE 2.—*Composition of guava juice.*[a]

Constituent.	Proportion.	Constituent.	Proportion.
	Per cent.		*Per cent.*
Sucrose	1.04	Pectin (alcohol precipitate)	0.96
Reducing sugars	4.18	Acidity (as H_2SO_4)	1.16

[a] Volume of drained juice, 1,200 cubic centimeters; Brix reading, 7.8.

The production of jelly from the juice of the guava is usually considered an easy task. Experienced jelly makers, however, frequently have difficulty in getting a firm consistency, and jelly factories in producing a uniform quality of jelly from guavas that have been

[7] Methods of Analysis of the Association of Official Agricultural Chemists. Revised to Nov. 1, 1919 Washington, D. C., 1920, p. 153.

obtained from different localities. These differences have been attributed to variations in the composition of the guava juices, which variations in turn were thought to be due to the widely differing localities and seasons, as well as to varietal differences, individual variations in the same variety, and varying stages of maturity of the fruit when it was used.

Variations due to widely differing localities and seasons.—To determine the effect of localities and seasons upon the jelly-making qualities of the juices, three guava-producing areas, representing widely differing conditions of climate, altitude, and season, were selected for study. Guavas from each of the areas were obtained from time to time and their juices were partially analyzed.

A uniform procedure was maintained throughout the experiment. In each test 5 pounds of medium ripe guavas were cooked with 2.5 pounds of water in an uncovered 2-gallon granite-ware container. After the mass had been constantly stirred to prevent it from sticking to the container and gently boiled for an hour to effect complete dissolution of the partly ripe fruit, it was allowed to drain overnight in a double cheesecloth bag. Only the juice which drained through without pressure was used in the experiment.

The moisture content of the fruit was determined by drying a pulped sample to constant weight at 100° C. Only the Brix corrected figures, pectin number, and acidity of the juices were determined, since the pectin and acid content are the only essential constituents for jelly making. The variations in the sugar content of the juice of a fruit are generally too slight to be of importance in this connection.

Table 3 gives the effect of localities and seasons on the composition of guava juices.

TABLE 3.—*Variations in the composition of guava juices due to location and season.*

Location.[1]	Season.	Moisture in guava.	Drained juice.	Juice.		
				Brix reading.	Pectin No.	Acidity (as H_2SO_4)
Windward Oahu:[2]		*Per cent.*	*Cubic centimeters.*	*Degrees.*		*Per cent.*
Kailua	Aug. 22, 1921	81.8	1,110	8.7	8¾	0.99
Do	Sept. 19, 1921	85.3	1,180	8.0	9½	1.10
Do	Oct. 4, 1921	82.6	1,100	9.4	9½	.82
Leeward Oahu:[3]						
Manoa	Sept. 8, 1921	86.5	1,130	8.1	7¾	1.50
Do	Sept. 16, 1921	83.3	1,180	8.3	8	1.58
Do	Sept. 22, 1921	82.3	1,185	8.1	8	1.66
Do	Nov. 8, 1921	.....	1,200	8.7	9	1.32
Pa'olo	Sept. 8, 1921	.....	1,490	6.9	8	1.39
Manoa	Feb. 2, 1922	.....	1,205	7.0	7¼	1.61
Mountain slopes:[4]						
Tantalus	Sept. 12, 1921	83.6	1,150	9.2	8½	1.24
Do	Jan. 11, 1922	87.8	1,415	8.4	7	1.09
Do	Jan. 27, 1922	87.0	1,200	7.7	6½	1.16
Do	Feb. 3, 1922	87.5	1,210	7.4	7	1.46

[1] The guavas from Kailua, Manoa, and Palolo were composite samples that were taken from ton lots of the fruit. Those from Tantalus were picked from only a few trees each time.
[2] Elevation 100 feet.
[3] Elevation 300 feet.
[4] Elevation 1,500 feet.

Table 3 shows that location has a very marked effect on the acidity of the juices of the guava. The proportion of acidity in the juices of guavas from the windward side of Oahu was less than 1 per cent, while in fruits from the leeward side it averaged nearly 1.5 per cent. The pectin content was highest in fruit from the windward side and lowest in that from the mountain slopes, but it was sufficiently

high in all instances for jelly making. The superiority for jelly making of guavas from the leeward side over those from the windward slopes is undoubtedly due to the high acidity of the former.

The variations due to seasons are not outstanding, but copious rainfall during the winter months increases the percentage of water and decreases the pectin content in the guava.

Variations due to varietal differences.—Thompson[8] gives analyses of six different varieties of guavas in Hawaii, one of which, the strawberry guava, was found to contain more acid than the other varieties, although it is less acid to the taste. The only guava which grows in sufficient quantity to be of practical importance for jelly making is the common guava, but for the sake of comparison the juices of three other varieties of guavas were tested. The results of the test are given in Table 4.

TABLE 4.—*Composition of juices from different varieties of guava.*

Variety.	Moisture in guava.	Drained juice.	Juice.				
			Brix reading.	Sucrose.	Reducing sugars.	Pectin No.	Acidity (as H_2SO_4).
	Per cent.	*Cubic centimeters.*	*Degrees.*	*Per cent.*	*Per cent.*		*Per cent.*
Sweet guava[1]	87.1	1,100	5.8	0.22	4.66	5½	0.31
Strawberry guava[2]	84.6	1,190	10.5	.....	.....	7	1.65
White guava[1]	.....	1,160	10.3	.....	.....	7½	1.99
Common guava[1]	87.5	1,200	7.8	1.04	4.18	6½	1.16

[1] *Psidium guayava.* [2] *P. cattleianum.*

It is apparent from Table 4 that all of the varieties of guava tested contain sufficient pectin for jelly making, and that all, with the exception of the sweet guava, have sufficient acid for jelly making.

Variations due to individual differences in the same variety.—The fruit from five guava bushes was kept in separate containers and their juices were compared. The bushes apparently were all of the common guava variety and grew in the same locality. The fruits selected from them were as near the same degree of ripeness as it was possible to select them. Table 5 gives the composition of the juices of the fruits from five trees.

TABLE 5.—*Composition of guava juices from the fruits of five trees growing in the same locality.*

No. of juice.	Drained juice.	Brix reading.	Pectin No.	Acidity (as H_2SO_4).	No. of juice.	Drained juice.	Brix reading.	Pectin No.	Acidity (as H_2SO_4).
	Cubic centimeters.	*Degrees.*		*Per cent.*		*Cubic centimeters.*	*Degrees.*		*Per cent.*
1	1,040	9.9	8½	2.19	4	1,235	8.4	8	2.06
2	1,050	9.2	7½	1.16	5	1,100	8.0	7½	.73
3	1,240	8.4	7½	1.09					

Table 5 shows striking variation in the acidity of the fruits, but uniformity in pectin content.

Individual variations have but little effect where the fruit is picked in ton lots. Variations in acidity would probably be rather large where the fruit is gathered from only a few bushes. Uniformity in acidity results when the fruits are picked from a large number of bushes.

[8] Hawaii Sta. Rpt. 1914, pp. 64, 67.

Variations due to picking at different stages of maturity.—Two lots of guavas were subdivided according to their stage of maturity and the juice of each subdivision was analyzed. The composition of the juices is shown in Table 6.

TABLE 6.—*Composition of the juices of guavas which were used at different stages of maturity.*

Location.	Stage of ripeness.	Drained juice.	Brix reading.	Pectin No.	Acidity (as H_2SO_4).	Total pectin extracted.[1]	Total acid extracted (as H_2SO_4).
		Cubic centimeters.	*Degrees.*		*Per cent.*	*Grams.*	*Grams.*
Manoa:							
Lot 1...	A; quite soft	1,365	8.5	7½	1.39	15.5	18.97
	B; full yellow; not soft	1,185	8.1	8½	1.66	14.8	19.67
	C; greenish yellow; rather firm.	815	9.4	10	2.55	12.3	20.78
Lot 2...	A; quite soft	1,585	7.1	7½	1.22	18.6	19.34
	C; greenish yellow; rather firm.	900	8.5	8½	1.95	11.5	17.55

[1] Pectin number×0.151×cubic centimeters of drained juice divided by 100.

From Table 6 it is apparent that (1) the quantity of juice increases as the fruit matures; (2) the pectin content of the juice decreases with increasing maturity, while the total quantity extracted increases; and (3) the proportion of acidity decreases very rapidly with increasing maturity. The total quantity extracted decreases slightly with increasing maturity in fruit of the lot 1 type and increases in fruit of the lot 2 type.

These experiments have demonstrated that the pectin content in guava fruit is uniformly high under all conditions, and that the acidity is subject to wide variations. Only the sourest guavas possible, with a good proportion of half-ripe fruit, should be selected for jelly making, because juices of low acidity produce jellies of inferior quality.

PROPORTION OF WATER TO FRUIT FOR GUAVA JELLY.

To 5-pound lots of fruit varying quantities of water were added to determine the best proportion of water to use for the extraction of juice. The results of the experiment are given in Table 7.

TABLE 7.—*Composition of guava juices obtained by using various proportions of water to 5-pound lots of fruit.*

Pounds of water to 5-pound lots of guavas.	Location.	Drained juice.	Juice.				
			Brix reading.	Pectin No.	Acidity (as H_2SO_4).	Total pectin extracted.[1]	Total acid extracted (as H_2SO_4).
		Cubic centimeters.	*Degrees.*		*Per cent.*	*Grams.*	*Grams.*
2.5	A, Manoa	1,130	8.1	7¾	1.50	13.2	16.95
3.75	B, Manoa	1,850	6.0	6¾	1.14	18.9	21.09
2.5	A, Manoa	1,480	7.1	7	1.51	15.6	22.34
3.75	B, Manoa	1,985	6.0	6	1.13	18.0	22.43
5	C, Manoa	2,390	5.5	5¾	1.03	20.7	24.62
2.5	A, Kailua	1,005	9.4	9¾	[2] 2.82	14.8	8.24
3.75	B, Kailua	1,690	6.5	7½	.83	18.5	14.03
5	C, Kailua	2,110	5.5	7	.81	22.3	17.09

[1] Pectin number ×0.151×cubic centimeters drained juice divided by 100.
[2] The high viscosity of this juice is probably the cause of the lack of concentration of acid.

Table 7 shows that with increasing proportions of water the pectin number decreases but the total pectin extracted increases. The percentage of acidity decreases in all the guava fruit except the Kailua guava, and the total acid extracted increases. The addition of over 5 pounds of water to 5 pounds of fruit would doubtless increase the total extraction, but the juice would be diluted to such an extent that prolonged boiling would be required to produce a jelly. When the cost of fruit is an important item it might be advisable to use a greater proportion of water than at other times, but even then a reboiling of the pulp, as is shown in the following paragraph, would be preferable.

SECOND EXTRACTION OF GUAVA JUICE.

The guava pulp remaining after the juice is drained off is often thrown away. Guava butter can be made from the pulp, but it is never as much in demand as guava jelly. The jelly factories have heretofore treated a large part of the pulp as waste.

To determine whether a second cooking would produce a juice sufficiently rich in pectin and acid to make jelly, the pulp which remained after the first juice had been boiled for an hour and then drained was reboiled with water for 30 minutes and allowed to drain overnight in a cheesecloth bag. A third cooking produced a muddy, dark-colored juice which was not adapted to jelly making. Table 8 gives the composition of the juices of the first and second boilings of two lots of guavas.

TABLE 8.—*Composition of juices from guavas which were boiled once and twice, respectively.*

Juice No.	Source of juice.	Drained juice.	Brix. reading.	Pectin No.	Acidity (as H_2SO_4).	Total pectin extracted.[1]	Total acid extracted (as H_2SO_4).
		Cubic centimeters.	*Degrees.*		*Per cent.*	*Grams.*	*Grams.*
A	5 pounds of fresh Kailua guava	1,100	8.3	7½	0.97	12.5	10.67
B	Pulp from A×1100 centimeters water	828	5.2	6¾	.64	8.4	5.30
C	5 pounds of fresh Kailua guava	890	9.2	8¼	1.04	11.1	9.26
D	Pulp from C×1335 centimeters water	1,150	6.6	7	.66	12.2	7.59

[1] Pectin number ×0.151×cubic centimeters drained juice divided by 100.

Table 8 shows that juice resulting from the second extraction contains almost as much pectin, but not nearly so high a proportion of acidity, as does the juice of the first extraction.

A comparison of the total pectin and the total acid contents of A and B with those of C and D shows that the second extraction contains practically as much total pectin and acid as does the first extraction when the latter is very concentrated, as in C; and that the total extraction in the second boiling is appreciably less when the juice of the first extraction is sufficiently dilute, as in A.

Jellies of good quality were made from juices of the second extraction. As a rule they were darker in color than those of the first extraction and did not possess as strong a guava flavor. Jelly having as high a sugar ratio as the juices of the first extraction can be made when sufficient acid is added to the juice of the second extraction.

Second-extraction guava juice is now being used by the various jelly companies of Hawaii to meet the demand for a low-priced pure fruit jelly. The only cost involved in producing jelly from the second-extraction juice lies in the additional 30 minutes required for boiling.

FIG. 1.—DETERMINING THE "PECTIN NUMBER" OF A FRUIT JUICE.

FIG. 2.—EFFECT OF VARYING PROPORTIONS OF SUGAR (½ TO 1½ CUPS) UPON THE AMOUNT OF JELLY PRODUCED BY 1 CUP OF FRUIT JUICE.

EFFECT OF VARYING PROPORTIONS OF SUGAR, PECTIN, AND ACID IN JELLY MAKING.

Considerable difference of opinion exists among investigators as to the best proportions of sugar, pectin, and acid to use in making jelly. N. E. Goldthwaite,[9] working with a wide variety of fruits, warns against the use of too much sugar. She considers 1 cupful of sugar to 1 cupful of juice to be the best proportion for most fruits. Cruess and McNair,[10] dealing with a number of California fruits, advocate the use of 1.5 pounds or more of sugar to 1 pound of fruit (equivalent 1.75 cupfuls of sugar to 1 cupful of juice). They found that jellies of good consistency resulted from juices containing from 0.5 to 1.5 per cent citric acid (equivalent to 0.7 to 2 per cent sulphuric acid), and that in the final jelly of good consistency the range of citric acid varied from 0.3 to 1.9 per cent (equivalent to 0.4 to 2.7 per cent sulphuric acid).

Goldthwaite,[11] working with the apple, pear, peach, and grape, concluded that an acidity greater than 0.5 per cent of the juice impaired the quality of the jelly. Later on, she obtained excellent jellies from currant and red raspberry juices having an acidity of 2.417 and 1.809 per cent, respectively. Campbell [12] found that apple juice having a pectin content of 1.25 per cent was necessary to produce a good commercial jelly, and that only 0.75 to 1 per cent was necessary to produce a jelly of delicate quality for household purposes. Barker,[13] working with apple cider, found that a satisfactory apple jelly could be made from juice containing 0.5 per cent of 1 per cent or more of pectin.

It is evident that the proportions of sugar, pectin, and acid can be varied within rather wide limits in jelly making, not only with different fruits but also with a single fruit.

VARIATION IN SUGAR.

Table 9 gives the results of tests with a jelly series [14] obtained by the addition of sugar in varying proportions to a constant proportion of juice from the common guava (Pl. I, Fig. 2).

TABLE 9.—*Results of using varying proportions of sugar with a constant proportion of juice from common guavas.*[a]

Sugar ratio.[b]	Weight of jelly.	Proportion of sugar.	Specific gravity 80° C.	Boiling temperature.	Consistency.	Taste.
	Grams.	*Per cent.*		° *C.*		
¾	269	55.7	1.27	102.5	Somewhat tough	Rather tart and strong flavored.
1	341	58.7	1.28	103.5	Good; a trifle tough	Tart; rather strong flavored.
1¼	398	62.8	1.28	104.0	Excellent	Excellent.
1½	446	67.3	1.29	104.7	Excellent; somewhat mellow.	Excellent; mild.
1¾	512	68.5	1.30	105.0	Excellent; mellow	Very mild; sweet.
2	564	70.9	1.31	106.0	Poor—gummy	Too sweet.

[a] Analysis of juice: Brix reading, 8.1; pectin number, 7½; acidity (as H_2SO_4), 1.19 per cent.
[b] In all of this work the term "sugar ratio" signifies the cupfuls of sugar added to 1 cupful of juice.

[9] Jour. Indus. and Engin. Chem., 1 (1909), No. 6, p. 333.
[10] Jour. Indus. and Engin. Chem., 8 (1916), No. 5, p. 417.
[11] Jour. Indus. and Engin. Chem., 2 (1910), No. 11, p. 457.
[12] Jour. Indus. and Engin. Chem., 12 (1920), No. 6, p. 558.
[13] Jour. Soc. Chem. Indus., 37 (1918), No. 14, p. 245.
[14] The procedure for obtaining a jelly series is given on p. 3.

Table 10 gives the results of tests with a jelly series obtained by the addition of sugar in varying proportions to a constant proportion of juice from the strawberry guava.

TABLE 10.—*Results of using varying proportions of sugar with a constant proportion of juice from the strawberry guava.*[1]

Sugar ratio.	Weight of jelly.	Proportion of sugar.	Specific gravity 80° C.	Boiling temperature.	Consistency.[2]	Taste.
	Grams.	*Per cent.*		°*C.*		
¾	244	61.5	1.28	103.2	Good; a trifle tough.....	Excellent; tart.
1	306	65.3	1.30	104.0	Excellent; rather firm.....	Excellent.
1¼	376	66.5	1.30	104.5	Excellent; mellow.....	Excellent; mild.
1½	445	67.4	1.30	105.5	Fair; a trifle gummy.....	Do.
1¾	468	74.8	1.32	106.5	Thick sirup.....	Sweet.

[1] Analysis of juice: Brix, 7.0; pectin number, 5½; acidity (as H_2SO_4), 0.99 per cent.
[2] Reference to "consistency" and "taste" columns of a jelly series shows that the ratio of sugar to use depends upon the quality of the jelly desired.

The following conclusions are evident from Tables 9 and 10:[15] (1) The maximum sugar ratio for the common guava is 1¾, and for the strawberry guava, 1½; (2) the quantity of jelly increases with the increase in sugar ratio, but the increase is not proportional; (3) the percentage of sugar, as well as the specific gravity, and the boiling temperature of the jelly, increase with the increase in the sugar ratio; (4) the texture changes, with increasing sugar ratio, from tough to excellent, mellow, gummy, or sirupy, in the order named; and (5) the jelly becomes gummy or sirupy when the proportion of added sugar in the jelly is about 68 per cent or more (approximately 70 per cent total sugar), and it becomes tough when the proportion of added sugar is less than 60 per cent (approximately 62 per cent total sugar).

Maximum sugar ratio of guava juices.—Table 11 gives in condensed form the maximum sugar ratio of a number of guava juices as determined by the foregoing method.

TABLE 11.—*Maximum sugar ratio of guava juices.*[a]

No. of juice.	Source of fruit.	Juice.				No. of juice.	Source of fruit.	Juice.			
		Brix reading.	Acidity (as H_2SO_4).	Pectin No.	Maximum sugar ratio.			Brix reading.	Acidity (as H_2SO_4).	Pectin No.	Maximum sugar ratio.
		Degrees.	*Per cent.*					*Degrees.*	*Per cent.*		
1	Manoa...	2.0	1.32	3¼	1¼	8	Manoa...	8.7	1.32	9	3¼
2	...do.....	5.5	1.05	5¾	1¾	9	Kailua...	4.7	.42	5½	1
3	...do.....	6.0	1.13	6	1¾	10	...do.....	6.7	.72	6¼	1¼
4	...do.....	7.1	1.51	7	2	11	...do.....	5.5	.81	7	1½
5	...do.....	7.2	1.03	7½	2¼	12	...do.....	6.5	.83	7½	1½
6	...do.....	8.5	1.39	7½	2¼	13	...do.....	9.4	.82	9¾	2¼
7	...do.....	8.1	1.66	8¼	2¼						

[a] The term "maximum sugar ratio" is used to denote the maximum number of cupfuls of sugar which can be added to one cupful of juice to produce a jelly of good consistency.

[15] It is not claimed that the figures given in a jelly series should be considered in the light of accurate quantitative results. The personal factor undoubtedly enters to a considerable extent. However, it has always been found possible to duplicate a series closely enough to draw substantially the same conclusions. The advantage of this method is that it affords a means of systematically studying the effect of variation in the sugar ratio.

From Table 11 it is apparent that there is a close relationship between the Brix reading of the Manoa juice, the pectin number, and the maximum sugar ratio. The sugar ratio is lower for the Kailua juices than it is for the Manoa juices due to the low acidity of the former.

Guava pectin table.—Table 12 has been constructed to give the maximum sugar ratio of a guava juice when either the Brix reading or the pectin number is known.

TABLE 12.—*Guava pectin table.*[1]

Brix reading.	Pectin No.	Maximum sugar ratio.	Brix reading.	Pectin No.	Maximum sugar ratio.	Brix reading.	Pectin No.	Maximum sugar ratio.
3.5	3¼–4½	1½	5.5–6.5	5¾–6½	1¾	7.5–8.5	7½–8¼	2¼
3.5–5.5	4½–5¾	1½	6.5–7.5	6½–7¼	2	8.5–9.5	8¼–9	2¼

[1] The above table is based upon the data given in Table 11 on Manoa guavas. The use of the Brix reading in this connection is not recommended because the relationship between the Brix and the pectin number is not a constant one. It is not to be inferred that the maximum sugar ratio is recommended as the best ratio. It merely indicates the maximum amount of sugar which will produce a jelly.

The juice should have an acidity of 1 per cent or more when the guava pectin table is used. If the acidity is less than 1 per cent, the maximum sugar ratio will be less. The texture of the jelly will be improved, however, if the acidity is increased rather than the sugar decreased.

Inversion of sugar.—In jelly making inversion of sugar is considered necessary to prevent crystallization of the sucrose. The amount of inversion required, however, has not been determined. Goldthwaite[16] failed to note any crystallization in jellies containing as low as 1.76 per cent or as high as 47.46 per cent of the added sugar inverted.

To discover the relationship between the sugar ratio and the percentage of inversion, the invert sugar was determined in each of several samples of jelly, the juice of which had the composition shown in Table 13.

TABLE 13.—*Composition of juices studied to determine the relationship between the sugar ratio and the percentage of inversion.*

Constituent.	Proportion.	Constituent.	Proportion.
	Per cent.		*Per cent.*
Sucrose	0.71	Pectin (alcohol precipitate)	1.06
Reducing sugar	3.01	Acidity (as H_2SO_4)	1.54

[16] Jour. Indus. and Engin. Chem., 2 (1910) No. 11, p. 459.

Table 14 shows the relation of sugar ratio to inversion of sugar.[17]

TABLE 14.—*Relation of sugar ratio to inversion of sugar.*

Sugar ratio.	Length of time required for cooking.	Weight of jelly.	Total sugar in jelly.[1]	Total sucrose added to jelly.[2]	Invert sugar in jelly.[3]	Sucrose in jelly.[4]	Sucrose inverted.[5]	Acid in jelly as (H_2SO_4).[6]	Specific gravity of jelly 80° C.	Final boiling temperature.
	Minutes.	*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		° *C.*
½	8½	177	61.64	57.48	29.16	33.74	41.32	2.13	.....	102.9
¾	8½	261	60.96	58.13	28.04	34.19	41.18	1.44	1.26	103.5
1	6½	335	62.42	60.21	26.68	36.96	38.61	1.13	1.28	104.0
1½	6	397	65.26	63.41	24.42	41.98	33.79	.95	1.29	104.0
1½	5½	467	66.19	64.61	21.74	45.46	29.64	.81	1.29	104.5
1¾	6	536	66.99	65.62	23.16	44.93	31.53	.70	1.30	104.5
2	5	584	70.05	68.79	22.42	48.69	29.22	.65	1.31	105.5

[1] Added sugar plus total sugars of juice divided by weight of jelly.
[2] Added sugar plus sucrose of juice divided by weight of jelly.
[3] Invert sugar (Munson-Walker method) divided by weight of jelly.
[4] (Percentage of invert sugar in jelly minus reducing sugars of juice) ×0.95 subtracted from percentage of total sucrose added to jelly.
[5] (Percentage of invert sugar in jelly minus reducing sugars of juice) ×0.95 divided by percentage of total sucrose added to jelly.
[6] (Percentage of acid in juice × 245) divided by weight of jelly.

From Table 14 it is evident that inversion takes place rather rapidly, only eight and one-half minutes being required to invert 41.30 per cent of the sucrose and five minutes to invert 29.22 per cent. The total percentage of invert sugar in the jelly resulting from a sugar ratio of one-half is only 6.74 per cent greater than that from a sugar ratio of 2. It seems probable, therefore, that there is sufficient inversion in the highest sugar ratios to prevent crystallization.

VARIATION IN ACIDITY.

To determine the effect upon guava jelly of varying the acidity of the juice, different quantities of citric acid were added to four portions of the same juice in which the pectin content remained constant. Table15 shows the variations in the jellies which were obtained from each portion.

TABLE 15.—*Variation in acidity of juice with a constant pectin content.*[a]

ACIDITY OF JUICE, 0.72 PER CENT.

Sugar ratio.	Weight of jelly.	Proportion of sugar to jelly.	Acidity of jelly (as H_2SO_4).[b]	Consistency.	Taste.
	Grams.	*Per cent.*	*Per cent.*		
¾	237	63.3	0.74	Firm; mellow	Good.
1	305	65.6	.57	.....do	Too sweet.
1¼	364	68.7	.48	.....do	Rather sweet.
1½	375	80.0	.46	Poor; gummy	Do.

ACIDITY OF JUICE, 1.17 PER CENT.

1¼	396	63.1	0.72	Excellent	Too tart.
1½	458	65.5	.62	.....do	Excellent.
1¾	514	68.0	.55	Excellent; a trifle mellow	Do.
2	541	73.9	.53	Poor; gummy	Too sweet.

[a] Analysis of juice: Brix, 6.7; pectin No. 6¾; acidity (as H_2SO_4), 0.72 per cent.
[b] (Percentage of acid in juice×245) divided by weight of jelly.

[17] No crystallization observed in any of the jellies after 6 months' standing.

TABLE 15.—*Variation in acidity of juice with a constant pectin content*—Continued.

ACIDITY OF JUICE, 1.4 PER CENT.

Sugar ratio.	Weight of jelly.	Proportion of sugar to jelly.	Acidity of jelly (as H_2SO_4).	Consistency.	Taste.
	Grams.	*Per cent.*	*Per cent.*		
1¾	518	67.5	0.66	Excellent	Excellent.
2	595	67.2	.57	Good; a trifle mellow	Do.
2¼	652	69.0	.52	Fair; mellow; a trifle gummy	A trifle sweet.
2½	688	72.6	.50	Very mellow; sirupy	Rather sweet.

ACIDITY OF JUICE, 1.62 PER CENT.

2½	705	70.9	0.56	Poor; rather mellow	Rather sweet.

From Table 15 it is concluded that the maximum sugar ratio increases with the acidity. A guava juice having a pectin number of 6¾, which is a medium juice, requires an acidity of at least 1.4 per cent for the highest sugar ratio. When the acidity is less than 1.4 per cent, the pectin can not swell to its maximum capacity.

To produce a jelly of about the proper tartness, a juice of 0.71 per cent acidity requires a sugar ratio of about three-fourths; a juice of 1.17 per cent acidity requires about 1½; and 1.4 per cent acidity, a sugar ratio of about 2.

Poor consistency results when the proportion of acidity in the jelly is approximately 0.5 per cent or less. Although the acidity can be much higher than 0.5 per cent without exerting a harmful effect on the consistency of the jelly, the taste becomes tart when the proportion of acid in the jelly is about 0.75 per cent or over. It seems, therefore, that the optimum acidity in guava jelly is between 0.6 and 0.75 per cent of the jelly.

VARIATION IN PECTIN.

The effect of varying the pectin content of guava juice with a constant proportion of acidity was studied by diluting portions of a guava juice with different quantities of water and bringing them to a uniform acidity with citric acid.

Table 16 shows the composition of the juices in which the proportion of acidity remained constant.

TABLE 16.—*Composition of guava juices in which the pectin content was varied and the acid content remained constant.*

Juice.	Brix reading.	Pectin No.	Acidity (as H_2SO_4).
	Degrees.		*Per cent.*
A	2.6	3½	1.40
B	5.1	5¾	1.40
C	7.9	7½	1.40

Table 17 shows the effect upon the jellies obtained from juices having a constant acidity but varying pectin contents.

TABLE 17.—*Effect upon the jellies obtained from juices having a constant acidity but varying pectin contents.*

Sugar ratio.	Weight of jelly.	Proportion of sugar to jelly.	Proportion of pectin in jelly.[1]	Consistency.	Taste.
	JUICE A.				
	Grams.	*Per cent.*	*Per cent.*		
¾	221	67.8	0.58	Excellent; tender	Too tart; mild.
1	294	68.0	.44	Very tender	Do.
1¼	346	72.3	.37	do	Tart; mild.
1½	400	75.0	.32	Sirupy	Good.
	JUICE B.				
1½	401	62.3	0.53	Excellent; tender	Tart.
1½	447	67.1	.48	do	Excellent.
1¾	519	67.4	.41	Very tender	Excellent; mild.
2	569	70.3	.37	do	Excellent; too sweet.
2¼	615	73.2	.35	Sirupy	Too sweet.
	JUICE C.				
1½	471	63.7	0.59	Excellent; firm	Excellent.
1¾	538	65.1	.52	do	Do.
2	576	69.4	.48	do	Rather sweet.
2¼	637	70.6	.44	Good; too tender	Too sweet.

[1] (Pectin number of juice×0.151×245) divided by (weight of jelly×100).

From Table 17 it is concluded that (1) the maximum sugar ratio increases with the pectin content; (2) a medium guava juice, which contains a pectin content of about 7½ is capable of forming a jelly having a sugar ratio of 2, provided sufficient acid is present; and (3) the consistency becomes too tender for a good jelly when the proportion of pectin in the jelly falls below about 0.48 per cent, and it becomes tough when the proportion of pectin is about 0.7 per cent or over.

OTHER HAWAIIAN FRUITS FOR JELLY MAKING.

Although there are many fruits in Hawaii that give palatable jellies, the actual number which can be used for jelly making is rather limited. Fruits that are commonly grown, such as the papaya, the avocado, and the mango, are not adapted to jelly making. "Papaya jelly" is occasionally made by adding pectin and citric acid to the papaya fruit. The mango contains sufficient pectin and acid for jelly making, but its yield is rather small to be of commercial use for jelly making, when the cost of the fruit and the time required to prepare the juice are considered.

Next in importance to the guava is the poha (*Physalis peruviana*), the jelly of which is much in demand. Commercial jelly companies in Hawaii are often unable to fill their orders for poha jelly, owing to the small quantity of poha fruit grown. The roselle (*Hibiscus sabdariffa*) ranks third in commercial importance. This fruit can generally be purchased on the markets during the fruiting season, but owing to its lack of popularity it is sold in small quantities.

Jelly from the Isabella grape (*Vitis labrusca*) is commonly made in the home. This grape can be purchased on the markets nearly the year round. The poha, roselle, and Isabella grape, together with the guava, are the only fruits which are grown in sufficient quantities to be of any importance for jelly making at present.

The methods worked out for the guava were used in making jelly from the grape, the roselle, and the poha.

ISABELLA GRAPE (Vitis labrusca).[18]

A representative juice (juice B, Table 18) showed the following analysis:

TABLE 18.—*Composition of Isabella grape juice.*

Constituent.	Proportion.	Constituent.	Proportion.
	Per cent.		*Per cent.*
Sucrose		Pectin (alcohol precipitate)	0.92
Reducing sugars	10.18	Acidity (as H_2SO_4)	1.21

Proportion of water to fruit for grape jelly.—To determine the best proportion of water to fruit, three 10-pound lots of grapes were cooked with varying proportions of water. Gentle boiling was maintained for only 20 minutes, during which time complete disintegration of the fruit had taken place. Each lot was then strained through cheesecloth, after which the pulp was squeezed to remove any remaining portions of the juice.

Table 19 shows the composition of grape juice made with different proportions of water and fruit.

TABLE 19.—*Composition of grape juices resulting from varying proportions of water and fruit.*

Juice.	Pounds of water to 10 pounds grapes.	Total juice.	Brix reading.	Total sugars.	Pectin No.	Acidity (as H_2SO_4).	Total[1] pectin extracted.	Total acid extracted (as H_2SO_4).
	Pounds.	*Cubic centimeters.*	*Degrees.*	*Per cent.*		*Per cent.*	*Grams.*	*Grams.*
A	0.5	3,140	15.2	11.91	5¼	1.37	36.6	43.00
B	3.0	4,055	12.6	10.18	4½	1.21	38.2	49.07
C	6.5	5,350	10.1	8.07	3¾	.95	38.6	50.83

[1] Pectin number ×0.222×cubic centimeters juice divided by 100.

A study of Table 19 shows that there is nothing to be gained in adding more than 3 pounds of water to 10 pounds of grapes, because a greater amount does not result in appreciably greater extraction.

[18] The Isabella variety has shown remarkable adaptability to the climatic and soil conditions of Hawaii and far surpasses all other varieties in acreage. It is usually spoken of as the Hawaiian grape.

Sugar ratio for grape jelly.—Table 20 shows the results of running a jelly series on each of the juices given in Table 19.

TABLE 20.—*Results of varying proportions of sugar, pectin, and acid in grape jelly.*[1]

JUICE A.

Sugar ratio.	Length of time required for cooking.	Weight of jelly.	Proportion of sugar added.	Total sugar in jelly.	Specific gravity 80° C.	Boiling temperatures.	Pectin in jelly.[2]	Acid in jelly.[3]	Consistency.	Taste.
	Min.	*Gms.*	*P. ct.*	*P. ct.*		*° C.*	*P. ct.*	*P. ct.*		
¾	3	342	43.8	52.4	1.21	102.0	0.83	0.98	Firm; tender.....	Too tart.
1	2½	378	52.9	60.6	1.25	103.0	.76	.89	.....do.....	Tart.
1¼	3½	432	57.9	64.6	1.27	103.5	.66	.78	.....do.....	Excellent.
1½	5	481	62.4	68.4	1.27	104.0	.60	.70	.....do.....	Do.
1¾	6	536	65.3	70.7	1.29	105.5	.53	.63	Mellow; lacks body.	Rather sweet.
2	7	608	65.8	70.6	1.28	105.5	.47	.55	.....do.....	Sweet.
JUICE B.										
¾	5	285	52.7	61.4	1.25	103.0	0.82	1.04	Firm; tender.....	Tart.
1	4	366	54.6	61.5	1.25	103.5	.63	.81	.....do.....	Excellent.
1¼	4	421	59.4	65.3	1.27	104.0	.55	.70	.....do.....	Do.
1½	5	445	67.4	73.0	1.29	105.0	.52	.67	Mellow; lacks body.	Rather sweet.
JUICE C.										
½	8	222	45.0	53.9	1.22	103.5	0.80	1.05	Firm; tender.....	Too tart.
¾	6½	266	56.4	63.8	1.26	104.5	.66	.88	.....do.....	Excellent.
1	5½	327	61.2	67.2	1.27	104.5	.54	.71	.....do.....	Do.
1¼	6	375	66.7	71.9	1.29	105.0	.47	.62	Mellow; lacks body.	Rather sweet.

[1] These jellies were left exposed to the air. All jellies having a sugar ratio of less than 1 developed mold. Those having a sugar ratio of 1 or more did not develop mold in 3 weeks' standing. No crystallization occurred in any of the lots.

[2] (Pectin number of juice ×0.222×245) divided by (weight of jelly×100).

[3] (Per cent acid in juice ×245) divided by weight of jelly.

From Table 20 it is evident that (1) the maximum sugar ratios of juices A, B, and C are 1½, 1¼, and 1, respectively; (2) the minimum proportion of pectin necessary to produce a jelly with sufficient body is about 0.56 per cent of the jelly; (3) the acidity of grape juice is probably never the limiting factor in jelly making, since the best flavors were produced with acidities of from 0.7 to 0.85 per cent of the jelly; (4) the jelly either lacks body or is of a mealy, granular texture whenever the total sugar in grape juice is about 67.0 per cent or over, and mold is likely to develop when the total sugar is less than about 60 per cent; and (5) the maximum sugar ratios of the grape juices, as determined by the above table, are about one-fourth lower than is given in the guava pectin table for the same pectin numbers.

NOTES ON JELLY MAKING FROM THE ISABELLA GRAPE.

Grape jelly is characterized by its very tender texture. Overcooking guava jelly results in a tough, hard consistency, but overcooking grape jelly causes an apparent breaking down of the pectin, which becomes a soft, granular mass. Grape jelly should not, therefore, be overcooked.

Too high a sugar ratio shows itself in lack of body, the jelly literally "melting in one's mouth." Undisturbed in the glass, this jelly may have the excellent sharp cleavage of a perfect jelly, but turned from its mold, it falls apart; or in other words, it has failed to jell.

Grape jelly should be made in small batches in a relatively large container so that evaporation will be rapid. Mealy or granular texture was found to result when the jelly was allowed to boil over 10 minutes.

All the grape jellies showed considerable tendency to "weep" regardless of the sugar ratio. "Weeping" is doubtless due to the weak nature of the colloidal membrane of the grape pectin. This is substantiated by the fact that adding a small amount of apple pectin to grape jelly will not only stop "weeping" but also greatly strengthen the texture of the jelly.

ROSELLE (Hibiscus sabdariffa).

Analysis of roselle juice.—Analysis of representative roselle juice (juice D, Table 21) gave the following results:

TABLE 21.—*Composition of roselle juice.*

Constituent.	Proportion.	Constituent.	Proportion.
	Per cent.		*Per cent.*
Sucrose		Pectin (alcohol precipitate)	0.95
Reducing sugars	0.21	Acidity (as H_2SO_4)	.91

Proportion of water to fruit for roselle jelly.—Varying amounts of water were added to five 3-pound lots of roselle to determine the best ratio of water to fruit from which the seed pods were not removed. Gentle boiling was maintained for 20 minutes, when it was found that the calyxes had completely disintegrated. Each lot was then strained through cheesecloth and squeezed as dry as possible.

Table 22 gives the composition of roselle juices made from varying proportions of water and fruit.

TABLE 22.—*Composition of roselle juices resulting from varying proportions of water and fruit.*

Juice.	Pounds of water to 3 pounds roselle.	Total juice.	Brix reading.	Pectin No.	Acidity (as H_2SO_4).	Total pectin extracted.[1]	Total acid extracted (as H_2SO_4).
	Pounds.	*Cubic centimeters*	*Degrees.*		*Per cent.*	*Grams.*	*Grams.*
A[2]	3						
B	4.5	1,660	5.2	6¼	1.17	19.3	19.42
C	6	2,120	4.3	6	.98	23.7	20.78
D	7.5	2,980	3.8	5	.85	27.7	25.33
E	9	3,730	3.1	4¼	.74	29.5	27.60

[1] Pectin number ×0.186×cubic centimeter of juice divided by 100.
[2] The juice formed a semijelly and would not pass through the cheesecloth bag.

Table 22 shows that with increasing proportions of water, both extraction of pectin and acidity increased; and that with dilution greater than that of juice D the pectin and acid content are so low that the juice can be sufficiently concentrated for jelly making only by prolonged boiling.

Composition of different parts of the roselle plant.—Wester [19] states that the leaves and stalks of the roselle can be used for jelly making and recommends the removal of the seed pods from the calyxes before cooking.

To learn whether these statements are applicable to the roselle in Hawaii, it was decided to experiment by separating a single whole roselle plant into three portions; (1) the mature fruit; (2) the immature fruit, blossoms, leaves, and tender ends of the stem; and (3) the remaining woody stalks. The mature fruits were then separated into calyxes and seed pods.

The juices, the composition of which is given in Table 22, were prepared as follows:

A. Calyxes weighing 1.91 pounds were separated from 3 pounds of mature fruit and boiled with 4.5 pounds of water for 20 minutes. The mass was then drained through a cheesecloth bag and squeezed as dry as possible.

B. Seed pods weighing 1.09 pounds were extracted from 3 pounds of mature fruit and boiled with 4.5 pounds of water for 20 minutes. The juice was then completely drained and boiled down.

C. Three pounds of mature fruit from which the seed pods were not removed were treated like that of series A.

D. The immature blossoms, leaves, etc., of a single roselle plant, weighing 0.93 pound, were chopped fine, boiled with 2 pounds of water for 30 minutes, and the juice was completely drained off.

E. The stalks, immature blossoms, leaves, etc., of a single roselle plant, weighing 0.98 pound, was cut into short lengths and boiled with 2 pounds of water for 30 minutes, after which the juice was completely drained off.

Table 23 gives the results of analysis of the roselle plant.

TABLE 23.—*Composition of the roselle plant.*

Parts of individual plant.	Total juice.	Brix reading.	Pectin No.	Acidity (as H_2SO_4).	Total pectin extracted.[1]	Total acid extracted (as H_2SO_4).
	Cubic centimeters	*Degrees.*		*Per cent.*	*Grams.*	*Grams.*
A, Calyxes	1,700	2.7	4½	0.78	13.4	13.26
B, Seed pod	315	3.4	2	.34	1.2	1.07
C, Whole fruit	1,680	3.4	4¾	.84	14.9	14.11
D, Leaves, stems, etc.[2]	660	3.2	2½	.64	3.1	4.22
E, Large stalks [2]	610	1.3	(3)	.10	.....	.61

[1] Pectin number ×0.186×cubic centimeter of juice divided by 100.
[2] Immature blossoms, leaves, etc. of a single plant.
[3] Trace.

From Table 23 it is apparent that the calyx of the roselle, as grown in Hawaii, is the only part of the plant containing sufficient pectin and acid to make it of value for jelly making. The leaves, tender shoots, and immature calyxes do not contain sufficient pectin

[19] Prog. Agr., 5 (1921), No. 7, p. 18.

to make them practicable for use in jelly making, and the flavor of the jelly made from them was not appetizing, although it had an excellent consistency.

Jellies made from the calyxes and from the whole fruit were compared for taste and consistency. It was impossible to detect any difference, and since the separation of calyxes and seed pods is a rather tedious process, the operation seems a needless expenditure of time.

Sugar ratio for roselle jelly.—Table 24 gives the results obtained from a jelly series made from juices B, D, and E.

TABLE 24.—*Results of varying proportions of sugar, pectin, and acid in roselle jelly.*

Sugar ratio.	Weight of jelly.	Proportion of sugar to jelly.[1]	Proportion of pectin in jelly.	Acidity of jelly (as H_2SO_4).	Consistency.	Taste.
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*		
JUICE B (seed pods).						
1	316	63.3	0.90	0.91	Good; firm; tender	Rather tart; strong flavor.
1¼	391	63.9	.73	.74	do	Do.
1½	460	65.2	.62	.63	Excellent; firm; tender	Excellent; strong flavor.
1¾	505	69.3	.56	.57	do	Excellent.
2	552	72.5	.52	.52	Too mellow	Too sweet; mild.
2¼	597	75.4	.48	.48	do	Too sweet.
JUICE D (leaves, stems, etc.).						
¼	68	73.5	3.34	3.06	Thick sirup	Too tart; strong flavor.
½	157	63.7	1.45	1.33	Fair; rather sirupy	Do.
¾	231	65.0	.98	.90	Good; firm; tender	Tart.
1	301	66.4	.75	.69	Excellent; firm; tender	Excellent; mild.
1¼	365	68.5	.62	.57	Excellent	Do.
1½	410	73.2	.55	.51	Slightly lacking in body	Do.
1¾	449	77.9	.51	.46	Lacking in body	Too sweet.
2	520	77.0	.44	.40	Sirupy	Do.
JUICE E (large stalks).						
¾	218	68.8	.89	.83	Firm; tender	Excellent; tart; mild.
1	287	69.7	.67	.63	do	Do.
1¼	334	74.8	.58	.54	Too mellow	Excellent; mild.
1½	381	78.7	.51	.48	Sirupy	Do.

[1] The proportion of total sugars in the jelly was not determined, since the fruit sugars in roselle juice are negligible.

From Table 24 it is concluded that (1) the maximum sugar ratio of juices B, D, and E is 1¾, 1¼, and 1, respectively; (2) roselle jelly containing about 72 per cent of sugar, or over, lacks body, or is sirupy and that containing less than about 63 per cent is of very poor consistency; (3) the minimum pectin content necessary to give sufficient body to roselle jelly is about 0.63 per cent of the jelly; (4) the best flavors are produced from juices having from 0.5 to 0.7 per cent of the jelly; and (4) the maximum sugar ratios, as determined by Table 24, are about one-fourth lower than is given in the guava pectin table for the same pectin number.

NOTES ON JELLY MAKING FROM ROSELLE.

Roselle jelly is comparatively easy to make. In order that it may have sufficient body, the mass should be boiled for some time after the first jelly test is made. A precipitate producing a very stiff guava jelly will produce a roselle jelly of proper consistency.

Roselle jelly somewhat resembles grape jelly in its tender consistency. However, it does not "weep" to the extent that the latter does.

The flavor of the roselle is very strong. Jellies that are made from too concentrated a juice, or which contain too small an amount of sugar, have a very strong flavor and a deep red color. This is probably the chief cause of the lack of popularity of the roselle jelly. If a medium juice—that is, one containing about 2.5 pounds of water to 1 pound of fruit—and the maximum sugar ratio are used, the resulting jelly will be milder flavored and lighter colored.

POHA (Physalis peruviana).

Analysis of poha juice.—Juice of the poha had the following composition:

TABLE 25.—*Composition of poha juice.*

Constituent.	Proportion.	Constituent.	Proportion.
	Per cent.		*Per cent.*
Sucrose	2.72	Pectin (alcohol precipitate)	0.43
Reducing sugars	10.42	Acidity (as H_2SO_4)	1.25

Proportion of water to fruit for poha jelly.—Varying amounts of water were added to 10-pound lots of poha to determine the best proportion of water to fruit. Gentle boiling was maintained for 20 minutes when it was found that complete disintegration had taken place. Each lot was then strained through cheesecloth and squeezed dry.

Table 26 shows the composition of juices obtained with varying proportions of water and fruit.

TABLE 26.—*Composition of poha juices resulting from varying proportions of water and fruit.*

Pounds of water to 10 pounds of pohas.	Total juice.	Brix reading.	Total sugar.	Pectin No.	Acidity (as H_2SO_4).	Total[1] pectin extracted.	Total acid extracted as (H_2SO_4).
	Cubic centimeters.	*Degrees.*	*Per cent.*		*Per cent.*	*Grams.*	*Grams.*
A (none)	2,410	18.9	15.80	4½	1.65	17.6	39.77
B (1.5)	3,040	15.7	13.12	3½	1.45	18.3	44.08
C (4)	3,735	13.3	11.11	3	1.19	19.3	44.45

[1] Pectin number ×0.172×cubic centimeter of juice divided by 100.

An examination of Table 26 shows that the best ratio of water to fruit was 1.5 pounds of water to 10 pounds of pohas. Extraction was then practically complete. With the higher dilutions the pectin content was too low for a good jelly juice.

Sugar ratio for poha jelly.—Table 27 gives the results obtained from a jelly series made from juices A, B, and C of Table 26.

TABLE 27.—*Results of varying proportions of sugar, pectin, and acid in poha jelly.*

JUICE A.[1]

Sugar ratio.	Weight of jelly.	Proportion of sugar to jelly.	Total sugar in jelly.	Proportion of pectin in jelly.	Proportion of acidity (as H_2SO_4).	Consistency.	Taste.
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		
1	338	59.2	70.6	0.53	1.20	Firm; somewhat tough.....	Tart; strong flavor.
1¼	394	63.5	73.3	.45	1.03	Firm; excellent.....	Fair; strong flavor.
1½	455	65.9	74.4	.39	.89	.....do.....	Excellent.
1¾	510	68.6	76.2	.35	.79	Firm; tender.....	Excellent; rather sweet.
2	541	74.0	81.1	.33	.75	Firm, but gummy.....	Rather sweet.

JUICE B.[2]

¾	248	60.5	73.5	0.60	1.43	Firm; somewhat tough.....	Tart.
1	323	61.9	71.9	.46	1.10	Excellent.....	Excellent.
1¼	388	64.4	72.7	.38	.91	.....do.....	Do.
[3] 1½	438	68.5	75.8	.34	.81	Excellent; tender.....	Do.

JUICE C.[2]

¾	241	62.2	73.5	0.52	1.21	Excellent; tender.....	Tart.
1	310	64.5	73.3	.41	.94	.....do.....	Excellent; mild.
1¼	372	67.2	74.5	.34	.78	.....do.....	Do.
1½	435	69.0	75.2	.29	.67	Firm; somewhat gummy...	Fair.
1¾	470	74.5	80.0	.27	.62	.....do.....	Poor.

[1] Dark colored and rather strong flavored series.
[2] Light colored and mild flavored series.
[3] Lack of juice prevented a higher sugar ratio. However, the tender consistency of the 1½ sugar ratio indicated that a higher ratio would produce a gummy or sirupy jelly.

From Table 27 it is concluded that (1) the maximum sugar ratio of juices A, B, and C is 1¾, 1½, and 1¼, respectively; (2) poha jelly is much higher in sugar content than is any other jelly studied; (3) a jelly of excellent consistency and taste will result when the total sugar content is from 70 to 75 per cent, but the jelly will be tough when the sugar ratio is less than 70 per cent, and gummy or sirupy when the sugar ratio is over 75 per cent; (4) the minimum proportion of pectin required to produce a good consistency is about 0.35; (5) the acidity of poha juice is probably never a limiting factor, but the best flavors were produced with acidities ranging from 0.8 to 1.0 per cent of the jelly; and (6) the maximum sugar ratio of the poha juices, as determined by the above table, are one-fourth to one-half higher than is given in the guava pectin table for the same pectin numbers.

NOTES ON JELLY MAKING FROM THE POHA.

It was found rather difficult to produce a poha jelly having the proper consistency. This is due to the fact that the resultant product becomes entirely too firm and tough when the jelly is allowed to cook until a test, suitable for guava jelly, is obtained. A very soft jelly test must be used to produce a good, tender consistency.

Owing to its very high sugar content, poha jelly has a tendency to crystallize. If the jelly is covered with paraffin, or hermetically capped, crystallization can usually be prevented.

CONSISTENCY OF JELLIES AS AFFECTED BY THE PHYSICAL PROPERTIES OF PECTIN.

A fruit jelly is essentially a colloidal gel, throughout which sugar and acid cause a uniform precipitation of the pectin. The character of the resultant gel depends primarily upon the physical properties of the pectin. Extensive studies have been made of the occurrence, extraction, and chemical composition of pectins.[20] Little mention, however, has been made of the difference in their physical properties, which, from the standpoint of jelly making, is of very great importance.

Observations on the physical difference in the alcohol precipitate of the four fruit juices (grape, roselle, guava, and poha) studied by the writer show that the properties of jellies are closely related to the physical properties of their pectins.

Table 28 shows the relation existing between the physical properties of pectins and the resultant jellies.

TABLE 28.—*Relation of the physical properties of pectins to the resultant jellies.*

Fruit.	Pectin.	Jelly.
Grape.....	Very weak pectin; very short fibers; pectin mass easily broken apart.	Tendency to weep; easily destroyed by overheating; low sugar content; tender; lacks body.
Roselle....	Weak pectin; short fibers; pectin mass easily broken apart.	Tender; lacks body.
Guava.....	Strong pectin; long fibers; pectin mass spongy and tenacious.	Dense; plenty of body; tough, if overcooked.
Poha.....	Very strong pectin; very long, dense fibers; pectin mass tough and stringy.	Very dense jelly; plenty of body; very tough, if overcooked; high sugar content.

Table 28 indicates that there is a gradation of the physical properties of the pectin and jelly from grape through, to, and including that from poha. The pectin gradually increases in length of fibers and tenacity from the gelatinous grape pectin to the dense, tough poha pectin. The jellies increase in body and density from the tender grape jelly of low sugar content to the tough poha jelly of high sugar content. It seems, therefore, that the physical character of the pectin is an important factor in determining the consistency of jelly.

APPLICATION OF THE GUAVA PECTIN TABLE TO OTHER FRUIT JUICES.

Reference of the pectin numbers of roselle, grape, and poha juices to the guava-pectin table shows that the maximum sugar ratio for the roselle and grape juice is too high by one-fourth and that the

[20] U. S. Dept. Agr., Bur. Chem. Bul. 94 (1905), pp. 67-89.

maximum sugar ratio for poha juice is too low by from one-fourth to one-half. These discrepancies are probably due to the physical differences in the pectins of the fruits.

If the physical differences are taken into consideration, the pectin table for guavas can be applied to most fruit juices. If the pectin precipitate forms a tender mass that is easily broken apart when the pectin number of unknown juice is being determined, one-fourth cupful of sugar should be subtracted from the maximum sugar ratio, as determined by reference of the pectin number to the guava-pectin table. If the mass is very dense and tenacious, one-fourth cupful should be added to the maximum sugar ratio.

SUMMARY.

Jelly making from tropical fruits is as yet an undeveloped industry.

The writer conducted a series of experiments for the purpose of developing a systematic procedure for making jelly from any kind of fruit containing sufficient pectin and acid.

A method is proposed for determining the "pectin number" which can be reduced to the approximate per cent of pectin by means of a common factor.

A table of the maximum ratio of sugar to guava juice is given for a series of pectin numbers. The table may be used for other fruit juices provided the character of the pectin is taken into account.

Experiments were made with the guava, grape, roselle, and poha to determine their value for jelly making.

The guava is especially well adapted for jelly making. It contains a strong, fibrous pectin, and usually has sufficient acid. The best proportion of water to guava is 0.75 pound to 1 pound of fruit. This produces a juice of 6 to 7 pectin number and 0.8 to 1.14 per cent acidity. The maximum sugar ratio for such a juice is 1½ to 1¾.

Location, altitude, season, variety, and differences in the same variety have a very marked effect on the acidity of guava juices. The pectin content of all guava juice is uniformly high. It is concluded, therefore, that acidity is the only important variable in guava juices and that failure to make jelly from the guava is directly traceable to lack of acidity in the juice.

The Isabella grape contains a very weak gelatinous pectin. It usually has sufficient acid for jelly making. The best proportion of water to fruit is 0.3 pound to 1 pound of grapes. This produces a juice of 4¼ pectin number and 1.21 per cent acidity. The maximum sugar ratio for this juice is 1¼.

The roselle contains a rather weak, short-fibered pectin, but the proportion of both pectin and acid is sufficient for jelly making. The best proportion of water to roselle is 2.5 pounds to 1 pound of fruit. This produces a juice with a pectin number of 5 and an acidity of 0.85 per cent. The maximum sugar ratio for this juice is 1¼.

The only part of the roselle from which jelly should be made is the calyx. Leaving the seed pods in during cooking does not affect the flavor.

The poha usually contains a very dense, long-fibered pectin. The proportion of pectin is quite low, but the acidity is usually high.

The best proportion of water to pohas is 0.15 pound to 1 pound of fruit. This produces a juice with a pectin number of 3½ and acidity of 1.45 per cent. The maximum sugar ratio of this juice is 1½.

Jellies of good consistency and flavor were obtained with the following variations in sugar, pectin, and acid content of the jelly: Guava jelly between 0.48 and 0.7 per cent pectin, 0.6 and 0.75 per cent acid, and 60 and 70 per cent sugar; grape jelly, 0.56 (minimum) pectin, between 0.7 and 0.85 per cent acid, and 60 and 67 per cent sugar; roselle jelly, 0.63 (minimum) pectin, between 0.5 and 0.7 per cent acid, and 63 and 72 per cent sugar; poha jelly, 0.35 (minimum) pectin, between 0.8 and 1.0 per cent acid, and 70 and 75 per cent sugar.

The consistency of a jelly is determined to a large extent by the physical properties of its pectin. A gelatinous, short-fibered pectin produces a weak, tender jelly, such as is obtained from the grape or roselle, while a dense, long-fibered pectin produces a dense, strong-textured jelly, such as is obtained from the guava or poha.

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